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(54) Title of the Invention: Copper Alloy for Lead Frames

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SPECIFICATION

Title of the Invention

Copper Alloy for Lead Frames

Claims

1. A copper alloy for lead frames characterized in that it contains, by weight %, 0.8 to 4.0% Ni and 0.2 to 4.0% Ti in a range satisfying (Ni%/Ti%) = 1 to 4, that it contains one of or both Fe and Co in a total amount of 0.01 to 1.0% and one of or both 0.1 to 1.0% Mn and 0.05 to 0.6% Mg in a total amount of 0.05 to 1.0% and the remainder is comprised essentially of Cu.

2. A copper alloy for lead frames characterized in that it contains, by weight %, 0.8 to 4.0% Ni and 0.2 to 4.0% Ti in a range satisfying (Ni%/Ti%) = 1 to 4, that it contains one of or both Fe and Co in a total amount of 0.01 to 1.0%, one of or both 0.1 to 1.0% Mn and 0.05 to 0.6% Mg, and 0.1 to 1.0% of Zn in a total amount of Zn + Mn + Mg of 0.05 to 1.0% and the remainder is comprised essentially of Cu.

Detailed Description of the Invention

[Field of Industrial Use]

This invention relates primarily to a copper alloy that is used for lead frames of semiconductor devices.

[Prior Art]

In general, the following characteristics are required of lead frames of integrated circuits containing semiconductor components.

(1) Good conductivity of electricity and heat

Superior electric conductivity and heat conductivity are required in order to transfer electric signals to the circuit components and to rapidly discharge heat that is generated in the circuit components to the outside.

(2) High mechanical strength

Finally, the lead tips of semiconductor devices are inserted into the sockets of various circuit substrates. It is necessary for the strength of the lead itself to be high because it is used for soldering, and, further, it is necessary that it has high fatigue strength that stands up to repeated bending of the lead part.

(3) Good heat resistance (high softening temperature)

Because the lead frame is exposed to high temperatures of 300 to 450°C in various processes such as die bonding, wire bonding and resin molding, it is essential that its mechanical strength is not decreased at temperatures of this order.

(4) The coefficient of thermal expansion should be close to that of the semiconductor chip or mold resin.

In order to prevent changes in the characteristics of semiconductor chips or deterioration of adhesiveness with mold resins caused by distortion due to differences in thermal expansion in assembly processes accompanied by heating, it is necessary for the lead frame material to have a coefficient of thermal expansion close to that of the semiconductor chip or the mold resin.

(5) Good plating capacity

In order to effect gold and silver plating of lead frame surfaces in parts that are die bonded to meet objectives, a material is necessary that gas a good capacity for being coated with a plating material and with which there will be few plating defects.

(6) Good solderability

In order to facilitate execution of soldering by the final user, a coating layer of Sn and solder is formed in advance on the external leads of the IC. Consequently, it is necessary that the lead frame material have good solder wetting properties and good peeling resistance of the solder (little deterioration of solder adhesiveness during long-term use).

(7) Good adhesiveness of the mold resin

Finally, many integrated circuits are of the resin molded type. In this case, it is necessary that there be good adhesiveness with the resin.

However, alloys such as Fe-Ni alloys like Fe-42% Ni and Fe-29%Ni-17%Co or Cu-base alloys such as copper containing iron or phosphor bronze which have been used conventionally as lead frame materials all have both advantages and disadvantages and some of the necessary properties must be sacrificed depending on the uses to which they are applied.

The Cu base alloy in these lead frame materials has far better heat conductivity and electric conductivity than Fe-Ni alloys, and it is also inexpensive, for which reason the amount used has begun to sharply increase in recent years and various types of alloys with improved mechanical strength and heat resistance, which are the defective points of Cu base alloys, have been proposed in the industrial world.

However, many of these alloys have a one-sided emphasis either on mechanical strength or electric conductivity and are inadequate when soldering properties are considered. For example, there are many instances in which alloy elements that are added for the purpose of improving mechanical strength impair the solder wetting properties and the solder peeling resistance in some way.

[Problems the Invention is Intended to Solve]

In light of these points, this invention provides a novel copper alloy which is endowed with both high strength and high electric conductivity and that has improved solder peeling resistance and suitable properties as a lead frame material.

[Means for Solving the Problems]

The inventors conducted experiments for the purpose of solving the problems described above. As the result, they arrived at this invention by discovering that alloys endowed with high strength, high electric conductivity and excellent solder peeling resistance are obtained by employing specific quantities of Fe and/or Co as well as Mn and/or Mg or Mn, Mg and Zn in the alloy.

Specifically, it is an alloy characterized in that, by weight %, in a copper alloy, it contains, by weight, 0.8 to 4.0% Ni and 0.2 to 4.0% Ti in a range satisfying (Ni%/Ti%) = 1 to 4, that it further contains one of or both Fe and Co in a total amount of 0.01 to 1.0% and one of or both 0.1 to 1.0% Mn and 0.05 to 0.6% Mg in a total amount of 0.05 to 1.0%, and, further, it is an alloy characterized in that it contains 0.1 to 1.0% Zn.

The Ni and Ti are deposited very finely as $Ni_3Ti$ and NiTi in the Cu matrix. An important point is that the compositional ratio is controlled within a suitable range in which the mechanical strength and the heat resistance of the alloy are improved without

excessively decreasing its electric conductivity. In short, when the Ni/Ti ratio, by weight %, is less than 1, an excess of Ti, or conversely, when the Ni/Ti ratio exceeds 4, Ni goes into solid solution in the Cu matrix, decreasing the electric conductivity of the alloy. Consequently, the Ni/Ti ratio is set to 1 to 4.

Next, in terms of the absolute quantities of Ni and Ti, when Ni is less than 0.8% or Ti is less than 0.2%, a sufficient mechanical strength cannot be maintained. Further, when Ni or Ti exceed 4.0%, the processability of the alloy deteriorates and there are also deleterious effects on plating properties and solder wettability. For this reason, the amounts are set at 0.8 to 4.0% Ni and 0.2 to 4.0% Ti.

Fe and Co are finely deposited in the alloy. They are elements that improve mechanical strength without causing excessive deterioration of solder wettability. When the amount is less than 0.01%, the effect is not sufficient. When it exceeds 1.0%, electric conductivity is greatly decreased. For this reason, the total for one of or both of these is set at 0.01 to 1.0%.

Mn, Mg and Zn are alloy elements that improve solder peeling resistance. At present, there are many points concerning the mechanism that are not clear. However, it can be presumed that diffusion and movement of the elements, which are in solid solution in minute amounts in the alloy, to the solder interface may be inhibited and that formation of fragile intermetallic compounds with Ti or Ni and Sn at the solder/matrix boundary may be impeded. When the content of Mn or Zn is less than 0.1% and the Mg content is less than 0.05%, a sufficient effect cannot be obtained. Conversely, when the content of Mn or Zn exceeds 1.0%, and the Mg content exceeds 0.6%, no further improvement is

obtained. In order not to being about excessive decrease in electric conductivity, the respective limits were set at 0.1 to 1.0% Mn, 0.05 to 0.6% Mg and 0.1 to 1.0% Zn.

When Mn, Zn and Mg are present together and when the sum exceeds 1.0%, the decrease in electric conductivity of the alloy cannot be ignored. For this reason, the total sum was set at 0.05 to 1.0%.

[Working Example]

We shall now describe this invention by means of a working example.

The alloys shown in Table 1 were dissolved in a high frequency dissolution induction furnace. They were then cast, forged and rolled to thickness of 5 mm by hot rolling. Next the oxide scale on the surface was removed by grinding, after which they were finished to a plate thickness of 0.25 mm at a final cold rolling ratio of 50% by repeated cold rolling and softening annealing and were then subjected to aging treatment at 450°C. Table 2 shows the results when these test materials were subjected to tests of electrical conductivity, tensile strength, solder wettability and solder peeling resistance. For solder wettability, soldering was performed on the basis of MIL-STD-202F Method 208D using test materials of 0.25 mm in thickness, 20 mm in width and 30 mm in length and the state of solder wetness was observed visually. For solder peeling resistance, the soldered test materials, which had been soldered by the method described above, were maintained for 500 hours at 150°C, after which they were bent to a curvature of a radius of 2 mm and evaluations were made based on the state of solder peeling from the matrix material when the bend was straightened out again. In Table 1 and Table 2, of the conventional alloys, test material no. 14 was a copper alloy containing Ni, no. 15 was a phosphor bronze high strength copper alloy and no.16 was a 42 Ni alloy.

Table 1

| Test material No. | Chemical composition (wt%) | | | | | | | | Ni/Ti | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ni | Ti | Fe | Co. | Mn | Mg | Zn | Cu | | |
| 1 | 0.5 | 1.8 | - | - | - | - | - | Balance | 0.28 | Comparative example |
| 2 | 2.0 | 0.1 | - | - | - | - | - | " | 20 | " |
| 3 | 2.0 | 1.0 | - | - | - | - | - | " | 2.0 | " |
| 4 | 1.4 | 0.5 | 0.09 | - | 0.16 | 0.20 | - | " | 2.8 | Alloy of this invention |
| 5 | 2.0 | 0.9 | 0.65 | - | 0.33 | 0.25 | - | " | 2.2 | " |
| 6 | 2.0 | 0.5 | - | 0.11 | 0.05 | 0.34 | - | " | 4.0 | " |
| 7 | 3.2 | 1.2 | - | 0.59 | 0.05 | 0.31 | - | " | 2.7 | " |
| 8 | 1.5 | 1.0 | 0.14 | 0.30 | 0.51 | 0.17 | - | " | 1.5 | " |
| 9 | 2.2 | 1.0 | 0.05 | - | 0.05 | 0.31 | 0.40 | " | 2.2 | " |
| 10 | 1.9 | 0.8 | 0.71 | - | 0.14 | 0.28 | 0.10 | " | 2.4 | " |
| 11 | 1.9 | 0.9 | - | 0.10 | 0.61 | 0.03 | 0.15 | " | 2.1 | " |
| 12 | 2.0 | 0.9 | - | 0.84 | 0.12 | 0.24 | 0.43 | " | 2.2 | " |
| 13 | 1.8 | 0.7 | 0.11 | 0.11 | 0.05 | 0.33 | 0.28 | " | 2.6 | " |
| 14 | 9.0Ni-2.3Sn-balCu | | | | | | | | - | Conventional alloy |
| 15 | 4.0Sn-0.20P-balCu | | | | | | | | - | " |
| 16 | 41Ni-balFe | | | | | | | | - | " |

Table 2

| Test material No. | Electric conductivity %IACS | Tensile strength kgf/m$^2$ | Solder wettability | Solder peeling resistance | Remarks |
|---|---|---|---|---|---|
| 1 | 20 | 64 | Excellent | Total surface peeled | Comparative example |
| 2 | 25 | 30 | " | Partial peeling | ' |
| 3 | 52 | 61 | " | Total surface peeled | " |
| 4 | 45 | 59 | " | Did not peel | Alloy of this invention |
| 5 | 34 | 68 | " | " | " |
| 6 | 42 | 62 | " | " | " |
| 7 | 38 | 66 | " | " | " |
| 8 | 35 | 67 | " | " | " |
| 9 | 41 | 64 | " | " | " |
| 10 | 28 | 68 | " | " | " |
| 11 | 38 | 63 | " | " | " |
| 12 | 29 | 70 | " | " | " |
| 13 | 33 | 66 | " | " | " |
| 14 | 12 | 56 | " | Partial peeling | Conventional alloy |
| 15 | 20 | 60 | " | " | " |
| 16 | 3 | 65 | " | Did not peel | " |

As should be evident from the results in Table 1 and Table 2, it can be see that the alloys of this invention were endowed with both high strength and high electric conductivity and that they also have excellent solder peeling resistance. As shown by the

comparative examples indicated by test materials 1 and 2 in which the Ni/Ti ratio departs from the range of 1 to 4, there were marked decreases in electric conductivity, with the advantages of the Cu alloy being lost. As shown for test material no. 3, solder peeling resistance deteriorated in alloys that did not contain Mn, Mg or Zn. The alloys of this invention exhibited electric conductivity of more than 10 times that of the conventional 42Ni alloy. Further, their strength was essentially equal to that of copper alloys containing Ni and high strength copper alloys containing Sn and P. However, their electric conductivity was high and their solder peeling resistance was also excellent.

[Effect of the Invention]

As described above, the alloys of this invention are endowed with both sufficient strength and electric conductivity as lead frame materials for semiconductor lead frames and they also have excellent solder peeling resistance, for which reason they can be lead frame materials of extremely high reliability.

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